SESSION # 4

A PRACTICAL APPROACH TO TRAVEL DEMAND MODELING IN SMALL AND MEDIUM SIZED AREAS

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ABSTRACT

Travel demand forecasting is the foundation of many transportation planning activities such as; 1) long term system planning; 2) sub-area/corridor study; 3) air quality conformity analysis; 4) transportation concurrency analysis; and 5) assessment of development impact fees. Many large urban area transportation planning agencies invest a significant portion of their staff time and resources in developing and maintaining their traffic models. However, small and medium-sized urban area planning agencies have fewer resources to dedicate to traffic model development. These communities can develop and maintain adequate traffic models, but they will have to use some practical and cost-effective approaches.

Through developing, updating, calibrating and applying several large and small urban area travel demand forecasting models, the author has accumulated some practical approaches for travel demand modeling. These practical approaches include roadway network and traffic analysis zone definition, network data collection and processing, socioeconomic variables and trip purpose categories selection for trip generations, gravity model coefficients fine tuning for trip distribution, and model calibration.

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Introduction:

Small to medium sized urban areas differ from large metropolitan areas in many ways. For example, in small to medium sized urban areas: 1) household incomes tend to be more homogeneous; 2) transit plays a smaller role in the transportation system; and 3) any single industry or institute may be a significant trip producer or attraction that warrants special consideration when modeling traffic. In terms of urban form, smaller urban areas are relatively newer and tend to have a less structured street network and census geography. In terms of applications, small urban area models are expected to provide long range travel demand projections, and assist in short range traffic operations analysis --- similar to a subarea model of a large regional model. These differences require that travel demand modeling in small urban areas be handled differently.

This paper describes some practical approaches in developing travel demand forecast models for small to medium sized urban areas. The first part of the paper is a general discussion of these techniques. The second part demonstrates how some of these techniques were applied in developing the Rogue Valley MPO Travel Demand Forecast Model as a case study.

1. Some Practical Approaches

Model development generally includes the following steps: traffic analysis zone (TAZ) and network definitions, the traditional four-step modeling process (trip generation, trip distribution, model split, trip assignment), model calibration/validation, and post model processing. This section describes some practical techniques for carrying out these steps.

1.1 TAZ Definitions

Traffic Analysis Zones (TAZ) are the building blocks of a model. A well-defined TAZ structure will contribute to accurate model trip distribution and traffic assignment. The smaller the zones, the better the model replicates the real world situation. In small to medium sized areas, it is more manageable to define traffic zones relatively small to improve model accuracy.

TAZ's are traditionally defined based on factors such as census and political boundaries, topographical barriers, homogeneous land use and roadway access. Many transportation planners prefer to follow census geography so that data collected in the decennial census can be used with minimal manipulation. This approach is especially applicable for areas with regular census geography and grid street patterns. However, in many small to medium sized urban areas, census boundaries tend to be more irregular and are sometimes too big to be used as a unit for defining TAZ's. Therefore, it is more desirable to reflect traffic access patterns rather than rigidly follow the census geography (see Figure 1). In this case, the relationship between TAZ and the census block can be established to facilitate the retrieval of census data.

In areas with grid street patterns, TAZ's have been traditionally defined with major arterials as their boundaries. To improve model performance, it may be more preferable to have TAZ straddle arterials, especially when transit services are present on the arterials (see Figure 2).

1.2 Trip Generation

Trip generation is the first step of the traditional four-step modeling process. In the trip general model, trips are divided into different categories by trip purposes. Examples of the trip purposes include Home-Based Work (HBW), Home-Based Shopping (HBS), Home-Based Other (HBO), and Non-Home Based (NHB). Generally, the more detailed the trip purpose categories, the more accurate the model.

Small to medium sized urban areas can sometimes be very different from large urban areas in terms of trip types composition. For example, a small city with a large university campus may have a high percentage of Home-Based College (HBC) trips. In this case, to more accurately represent college travels, it is a good idea to establish a HBC trip type. Similarly, small urban areas with a focus on tourism will have a large proportion of recreational trips that may warrant a special trip type called Home-Based Recreational trips (HBR).

(See hard copy for Figures 1 and 2)

Trip generation consists of two sub-models including the trip production model and trip attraction model. Typically, trip production models deal with the trip ends associated with the traveler’s home, and trip attraction models deal with the trip ends associated with activities at places other than the traveler’s home.

Lodging places such as hotels and motels are frequently defined as trip attractions. For urban areas with a heavy emphasis on tourism, however, it makes more sense to capture lodging places in both trip production and trip attraction models. That is, hotel and motel employees commuting to work should be accounted for in the trip attraction model, while tourists leaving lodging places to visit recreational sites and other places should be accounted for in the trip production model. Consequently, it is a good idea to define an additional trip type called Lodging-Based Recreation (LBR) to more realistically simulate recreational trip distribution patterns. Accounting LBR trips in the trip production model is especially important if trip production is to be held “constant” in the trip balancing process. This is because recreational trips leaving lodging places are made mostly by residents from outside of the modeling areas.

Generally speaking, trip production models deal with travel patterns related to demographic and socio-economic characteristics of households in the TAZ. The single most important variable used to forecast household travel is the household size. Other important variables include home type, income level or auto ownership, number of workers, etc. The more variables used, the more extensive the data required for the model.

For trip production, most large urban areas use some type of cross-classification model that range from simple cross-classification of number of trips and household size to more complicated multivariable cross-classifications. Cross-classification modeling is especially suited to large urban areas where household socio-economic characteristics are more diverse.

Household socio-economic characteristics in small to medium sized urban areas are usually more homogeneous than those found in large urban areas, the need for developing multivariable cross-classification is somewhat less significant to the modeling effort. Furthermore, many small urban areas planners have limited resources (in terms of time, funding, tools and local data) to develop refined cross-classification models for base-year conditions, not to mention the resources needed to forecast these variables for horizon year conditions.

A basic rule of thumb for determining what variables should be included in the cross-classification model is that the variable must be forecastable and will be forecasted. Small urban areas may find it to be more cost effective to develop a set of trip rate adjustment factors to account for variations in travel patterns as an alternative to developing a more complicated cross-classification model. For example, household income has significant impact on household travel, but if it cannot or will not be forecasted, then the income levels can be represented in the model by generalizing the information by geographic areas and their underlying property values.

1.3 Trip Distribution

Trip distribution and trip assignment are the second and fourth steps in the four-step travel demand modeling process. In the trip distribution step, the trip productions and the attractions are converted to trip origins and destinations; trip origin zones and destination zones are paired. The Gravity model is the most commonly used model for trip distribution. The gravity model coefficient, called the friction factor, is a measurement of spatial separation between trip origin and destination zone pairs. Some modeling packages, such as QRS-II and Tmodel2, use a set of default functions called the gamma function to calculate friction factors. The gamma function is stated as the following:

$$\mathbf{F_{ij} = a * t_{ij}^{\,b} * e^{\,c * t_{ij}}}$$

Where:	F_{ij}	=	the friction factor relating the spatial separation between zones i and j
	a, b, c	=	gamma coefficients
	t_{ij}	=	travel time between zone i and zone j
	e	=	the base of natural logarithms

The coefficients in the gamma function vary according to the size and accessibility of a region. Modeling packages with gravity models built-in usually provide sets of default coefficients for areas of different sizes.

Some modeling packages, such as EMME/2, do not come with default formula and coefficients. Users of those modeling packages will need to supply the model with their own functions and coefficients. The coefficients used in the initial model runs need to be examined and fine tuned in the later model calibration process to achieve desirable trip length for each of the trip purpose types defined in the trip generation step. Since each trip purpose type requires a unique set of coefficients and each gamma function needs three different coefficients, to find several suitable sets of gamma coefficients for different trip purpose types can be very time consuming.

Alternatively, modelers can use a simpler exponential function to determine friction factors:

$$\mathbf{F_{ij} = \exp(-ßT_{ij})}$$

Where:	$\mathbf{F_{ij}}$:	friction factor between zones i and j
	$\mathbf{T_{ij}}$:	travel time between zones i and j
	ß:	distribution parameter

Since this function only has one coefficient, it is much easier to test and find an acceptable value than the gamma function.

1.4 Mode Choice

Mode choice is the third and probably most complicated step in the four-step modeling process. It estimates the modal shares of the travel market when given two sets of data: 1) the time and cost characteristics of the various competing modes (typically transit and private vehicles) and 2) the demographic and socio-economic characteristics of area residents. The mode choice model requires extensive local data to develop. Since the transit mode share in many small urban areas is

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less than one or two percent of all trips, small urban area modelers should evaluate the objectives of the mode choice model and the cost-effectiveness of achieving the objectives before committing their resources.

1.5 Traffic Assignment:

Traffic assignment is the fourth step of the four-step process. The traffic assignment process is driven by the relationship of the assigned volume and the resulting speed caused by congestion. This relationship is defined by volume-delay functions. Theoretically, volume delay functions do not vary with urban area sizes.

Traffic assignment is an iterative process. Modeling packages geared toward small to medium sized areas, such as QRS-II and Tmodel2, have a built-in feedback loop between trip distribution and trip assignment for each iteration of the model run to more realistically simulate traffic conditions. However, other modeling packages, such as EMME/2, do not have the automatic feedback loop. It is up to the users to implement this feedback loop in the modeling process. The feedback loop is extremely important in the testing of road improvement alternatives and of road closures.

1.6 Model Calibration

Model calibration/validation represents the final step in the model development process. In this step, base year model outputs, primarily traffic assignments, are compared to observed base year conditions to ensure that the model can reasonably replicate real world situations. The comparisons are usually done at the following levels:

- Link specific volumes
- Screenlines (check trip distribution and assignment)
- Cordon lines (checks both trip generation and distribution)
- Regional statistics such as RMSE (root mean square error) by facility type and volume groups

In the initial model test runs it is very likely that observed and estimated screenline volumes will not be within an acceptable range of values. An analysis of the source of the error will show where adjustments to one or more of the upper level models may be required. These adjustments may include land use inputs, trip generation rates, roadway network and link attributes, traffic counts, gravity model coefficients, volume delay functions, etc.

Model calibration methodologies and procedures are well documented in various literature and research papers. Since small urban areas rarely have local traffic survey data, trip generation rates are frequently borrowed from other areas or adopted from national averages. This practice makes validation of trip generation rates very important.

Residential trip production rates should be evaluated first by comparing screenline total assigned trips to actual total ground counts. If the total assignment is higher than the total ground count, it is very likely that trip production rates are too high and should be adjusted down, provided that trip production is held constant in the trip balancing. On the other hand, if total assignment is lower than total ground counts, trip production rates may be too low and thus should be adjusted up. Once total assignments and total counts are within a reasonable range, trip generation rates for other land use types can be validated.

To validate trip generation rates for individual land use types, cordon lines can be developed around various areas with homogeneous land uses, such as single family residential areas, shopping centers, office complexes, and industrial parks. For example, if observed total base-year traffic counts along a cordon line around a shopping center are significantly higher than the model assignment, two possibilities exist: the trip rates used for the retail category is too low and/or the number of retail businesses/employees is under counted. This would require the validation of the number of businesses and employees first, then the adjustment of the trip attraction rates for the business types within the shopping center.

2. A Case Study – the Rogue Valley MPO Model

Rogue Valley Council of Governments (RVCOG), the federal designated Metropolitan Planning Organization (MPO) for the greater Medford urbanized area, is located in Jefferson County, Southern Oregon. It encompasses the cities of Medford, Central Point, Phoenix and White City and part of Jackson County with a population of approximately 100,000. Using the EMME/2 software, the regional model was developed in late 1995 to support the development of the MPO Long Range Transportation Plan. In addition to supporting the regional transportation system analysis and planning efforts, the local jurisdictions also expected the model to simulate traffic flow in relative detail to assist short-range traffic operations analysis.

2.1 TAZ and Network Definition

To meet the long range planning needs and local jurisdictions' expectations, TAZ's were defined as fairly small zones and network attributes were defined based on detailed roadway attributes.

Like many small urban areas, the Rogue Valley MPO has very irregular census geography. This is especially the case in its outlying areas. If TAZs are defined by following census boundaries, the TAZ in outlying areas would be too large to produce model results for evaluating specific roadway capacity deficiencies and improvement alternatives. Because the area has GIS based property parcel mapping, it was determined that census boundaries would be followed in the areas with grid street patterns. TAZs in outlying areas were defined by following property parcel boundaries and by considering how traffic accessed the roadway network.

To increase work efficiency, the roadway network was created in the spreadsheet file with detailed roadway geometrics and intersection traffic control types inventoried. Link capacities were calculated based on general per lane capacity adjusted by area types (CBD or urban peripherals, for example), lane width, median types, shoulder presence, down stream intersection traffic control types and the classification of cross street relative to the street under study. Other network data were also processed in a similar manner. The spreadsheet then generated a network file in the EMME/2 format, which was directly imported into the EMME/2 for model runs.

2.2 Trip Production Model and Jackson County Household Activity Survey

The trip production model was developed based on the 1995 Jackson County Household Activity Survey (JCHAS). Household activity surveys were rarely conducted for medium to small urban areas because of the cost involved. In 1995, with the help of the Oregon Department of Transportation and Portland Metro, the Rogue Valley MPO joined the other three MPOs in the state and conducted the survey. The Sample households were recruited from a random listing of telephone exchanges within the study area. Each household in the sample was assigned a specific two-day period for which detailed data on all activities (even if travel was not involved) was collected. Household data collected included income, auto ownership, household size, dwelling type and personal data pertained to gender, age, ethnicity, employment background, and student status. The survey collected data from 1,781 valid sample households.

The survey revealed that household size was the single most important variable in explaining household travel patterns. Table1 shows the relationship between household size and number of average weekday trips. Also shown in this table is the result of the 1990 NATIONWIDE PERSONAL TRANSPORTATION SURVEY (NPTS) for comparison.

Table 1 - Household Trip Rates by Household Size
JCHAS vs. NPTS

Household Size	Person Trips		Vehicle Trips	
	JCHAS	NPTS	JCHAS	NPTS
One	3.7	3.7	2.9	3.2
Two	6.9	7.5	5.2	6.6
Three	12.3	10.6	8.1	9.4
Four & +	17.2	14.5*	8.6	12.4*

* Note: Estimated due to different number of categories between the two data sets.

As shown in the above table, compared to the national average, person trip rates for different household sizes in Jackson County are consistent with or close to the national averages, however, vehicle trip rates appeared to be lower across the board. Other key findings of the household activity survey are summarized in Tables 2, 3 and 4.

Table 2 - Household Income and Trip Rates

Household Income	Person trips	Vehicle trips
$0 - $19,999	6.3	3.6
$20,000 - $34,999	8.8	5.7
$35,000 - $49,999	11.3	7.0
$50,000 or More	11.1	7.5

Table 3 - Vehicle Trip Rates Cross-classification Household Size and Household Income

Household	Household Size				
	One	Two	Three	Four	Avg.
$0 - $19,999	2.44	3.51	6.29	5.60	3.60
$20,000 - $34,999	3.66	5.10	7.86	8.16	5.72
$35,000 - $49,999	3.17	5.51	8.40	9.09	7.00
$50,000 or More	4.06	6.25	8.91	10.25	7.54
Unreported	2.52	5.31	8.44	8.39	5.57
Weighted Average	2.93	5.18	8.08	8.55	5.78

Based on the household activity survey, trip purposes were divided into Home-Based Work (HBW), Home-Based Shopping (HBShp), Home Based School (HBSch), Home-Based Other (HBO), Non Home Based Work (NHBW) and Non-Home Based Other (NHBO). The percentages of trip type composition are shown in Table 4.

Table 4 - Distribution of Weekday Trips by Trip Purposes

Trip Purpose	Person Trips		Vehicle Trips	
HBW	4040	16.72%	3582	22.62%
HBShp	2906	12.03%	1968	12.43%
HBSch	1961	8.12%	302	1.91%
HBO	8679	35.92%	5562	35.12%
NHBW	1187	4.91%	1007	6.36%
NHBO	5391	22.31%	3416	21.57%
Total	24164	100.00%	15837	100.00%

2.2 Trip Attraction Model

In the travel demand modeling process, employment data was used to measure the attraction side of travel demand. Employment data was obtained from the State Employment Office (SEO). The data were compiled for the State Unemployment Insurance Program at the county level. The data were cross-checked against employment data contained in the County Business Patterns and was then geo-coded and field validated. To improve the estimation of trip rates and trip distributions, employment data was divided into detailed categories based on their trip attraction levels as shown in Table 5.

The trip generation model was implemented in a spreadsheet program to increase efficiency. The output of the spread sheet program was in an origin and destination format and could be directly imported into the EMME/2 program for trip distribution and assignment.

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Table 5 - Trip Attraction Rates

Employment Type	HBW Trips	Non Work Trips
High Retail (i.e., super markets)	2.2 /employee	20.0 /employee
General Retail	2.2 /employee	13.0 /employee
Low Retail	2.2 /employee	4.0 /employee
Restaurant and High Services	2.2 /employee	8.0 /employee
General Services/Recreation	2.2 /employee	5.0 /employee
Lodge	2.2 /employee	1.0 /employee
Whole Sale, Trade and Construction	2.2 /employee	1.0 /employee
Industrial	2.2 /employee	0.5 /employee
Government/Education	2.2 /employee	4.0 /employee
Parks	N/A	6.0 /acre
Households	N/A	1.2 /household

2.3 Trip Distribution and Assignment

The gravity model was used for trip distribution and the exponential function $\mathbf{F_{ij} = exp(-ßT_{ij})}$ as described earlier was used to derive friction factors. The distribution parameter **ß** for different trip purposes is shown in Table 6.

Table 6 -Trip Distribution Parameters by Trip Purposes

Trip Purpose	HBW	HBShp	HBSch	HBO	NHBW	NHBO
ß	0.09	0.11	0.11	0.11	0.20	0.20

Since EMME/2 does not have an automatic feedback loop to link trip assignment and trip distribution, a macro feedback loop was implemented in the model as follows:

- The initial (first iteration) traffic assignment was performed using free flow speeds;
- The resultant zone to zone impedance metrics was then looped back into the trip distribution step and trips were redistributed and reassigned (second iteration);
- The second iteration impedance metrics were averaged with the first iteration impedance metrics which were then used as input into the third iteration;
- The feedback loop was repeated in the subsequent iteration runs until traffic assignments reached equilibrium (which usually takes about four to five iterations).

2.4. Model Calibration Results

Because of these detailed approaches, model calibration was very successful (see Table 7 and Figure 3). All indicators met or exceeded the targets set in the Oregon Statewide Travel Demand Modeling Guidelines.

Table 7. Trip Length Distribution Frequency by Trip Type*
(in minutes, exclude terminal times)

Trip Type	Model	Survey	Difference
HBW	10.62	12.33	86.1%
HBShop	10.11	9.25	109.3%
HBSchl	7.67	9.35	82.0%
HBO	8.20	9.46	86.7%
NHBW	7.41	8.75	84.7%
NHBO	6.47	8.40	77.0%
All	9.04	9.67	93.5%

* Note: It is acceptable that model results are slightly lower than the survey due to the fact that survey respondents tended to round up their travel times instead of reporting the actual times.

(See hard copy for Figure 3. Link Scattergram)

Conclusions:

Smaller urban areas differ from large metropolitan areas in many ways. Many small urban areas do not have sufficient resources to conduct expensive travel surveys, nor to recruit and retain a team of very specialized technical staff. Smaller communities have smaller geographic areas and fewer streets to model. Small urban area household income tends to be a more homogeneous socio-economic factor; transit plays a smaller role in transportation systems than in larger urban areas; any single industry or institute may be a significant trip producer or attraction that warrants special consideration. Smaller urban areas have a relatively newer urban form and tend to have a less structured street network and census geography. These differences make it necessary to handle travel demand modeling in small urban areas differently than it is handled in larger urban areas. As demonstrated in the case study, with appropriate care, transportation planners working in small urban areas can turn disadvantages into advantages while developing and maintaining an adequate model to support short and long-range transportation planning activities.

References:

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